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Division of Forest Insect Investigations

STUDIES OF METHODS OF IMPROVING THE ACCURACY AND GENERAL EFFICIENCY OF SPRUCE BUDWORM SURVEYS: 1951 PROGRESS REPORT

Forest Insect Laboratory
Coeur d'Alene, Idaho
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To: J. A. Beal, In Charge, Forest Insect Investigations

From: James C. Evenden, P. O. Box 630, Coeur d'Alene, Idaho

Subject: Laboratory Reports

Enclosed are progress reports on Work Project I-c-9 by Denton, and I-c-1 by Johnson.

Mr. Denton's report covers results of studies conducted during 1951 on the methods of improving the accuracy and general efficiency of spruce budworm surveys. Though the work is quite preliminary, some trends are indicated which may be quite helpful in future spruce budworm surveys. His correlation of overwintering budworm populations and subsequent tree defoliation, in particular, is quite encouraging. This, of course, will be helpful in determining the need for control the following season. Though his preliminary results would appear to be clear-cut, the study has brought out the many difficulties involved in working with the spruce budworm. We are sure that any who have worked on the biology of this insect will appreciate the difficulties which Mr. Denton encountered. However, we feel that he has made a definite contribution to the knowledge of the budworm, its habits, and the means of determining the need for controlling it.

The report by Mr. Johnson is largely concerned with a description of the procedures set up this past year to conduct studies on the adaptability and effectiveness of the ponderosa pine risk rating system in the northern Rocky Mountains. Though some results are given from the 1951 work, they are decidedly preliminary in nature. It is hoped that additional work this year and during the next few years will bolster these results and provide the necessary clues as to the system's effectiveness in this region.

cc: Portland
Berkeley
Ogden
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rcd 579

STUDIES OF METHODS OF IMPROVING THE ACCURACY AND GENERAL EFFICIENCY OF SPRUCE BUDWORM SURVEYS: 1951 PROGRESS REPORT 1/

INTRODUCTION

High stumpage values in recent years, together with a greatly increased demand for Christmas trees, has placed Douglas-fir among the top ranking species in the northern Rocky Mountains in regard to its economic importance. Coincidentally, protection of Douglas-fir from the ravages of forest insects has become a major concern among persons engaged in timberland management for both sawlogs and Christmas trees.

A serious insect enemy of Douglas-fir is the spruce budworm.2/ Depredations of this insect during past outbreaks in this region are a matter of record. Suffice to say, the budworm is a primary forest insect pest whose defoliations, if continued over a period of several years in epidemic status, are capable of destroying vast amounts of timber. Weakening of trees, inviting bark beetle attack, and greatly reduced increment may result from less serious defoliation, while even one season's feeding may destroy the aesthetic value of Douglas-fir Christmas trees for several years to come.

For the past 2 years budworm infestations in Douglas-fir forests in this region have shown an alarming increase over some ½ million acres each year. Added to the acreage of older infestations, this gives a total infested area of nearly 1½ million acres in the northern Rockies. No recent budworm-caused tree mortality of any consequence has occurred, although in some instances outbreaks of several years' standing now threaten forest cover over extensive areas. In addition, a persistent outbreak that originated in the South Fork Primitive Area, Montana, in 1942, spread into the adjacent Swan River valley and seems to be continuing its spread toward valuable Christmas tree stands in the northern part of the state.

The necessity of conducting budworm surveys to determine the extent and severity of infestations in this region became evident when a method of applying control over large forested areas by aerial spraying was developed in 1947 for a serious tussock moth outbreak. In this same year provisions of the Forest Pest Control Act delegated to the Bureau of Entomology and Plant Quarantine the responsibility of "conducting surveys on any forest lands to detect and appraise infestations of forest insect pests....." Since that time annual budworm surveys have been conducted in the northern Rocky Mountains. Limited personnel and funds necessarily have restricted these surveys to extensive reconnaissances in order to observe budworm conditions over 3 million acres or more of host type. Likewise, collection of data has been limited to mapping the extent of infestations and broadly indicating their severity as light, moderate, heavy, or very heavy. This type of survey serves the purpose for obtaining a general picture of budworm conditions throughout the region, or for making initial examinations of new outbreaks. It does not, however, always provide information that will permit evaluation of the data in regard to the need for recommending control.

1/ Prepared by Robert E. Denton, Entomologist.
2/ Choristoneura fumiferana (Clem.).

In this region the budworm presents a two-fold problem: protection of commercial timber, and prevention of infestations in Christmas tree stands. In the latter case the solution is not difficult - control is necessary at the first signs of budworm infestation. In the former case the situation is quite different. As yet, loss of increment is not recognized as a factor of sufficient economic importance to justify control. Rather, control becomes necessary when the trees or timber stands will not endure further defoliation without excessive mortality.

In facing the task of preventing tree mortality the objective is to wait as long as possible before recommending control. Past experience has shown that many budworm outbreaks subside of their own accord before tree mortality of any consequence occurs. Also, examples might be cited where survival of stands on severely defoliated areas seems hopeless; yet they often do survive with little permanent damage. Thus, determining the critical year, or the time when control becomes necessary, will vary for different forest environments and for different types of infestations. The goal is to determine methods whereby these conditions may be measured.

In view of the foregoing it was evident that if control seems advisable more intensive surveys are needed to measure existing budworm populations and to determine their immediate trends. Even more important is the need to know, or be able to predict, population densities and the degree of damage that will occur during the next season. Thus, if it were known in advance that the next season's population would be too small to cause further economic damage or tree mortality, thousands of dollars might be saved by exclusion of such areas from a control program.

The purpose of this study, therefore, is to develop a type of survey that will determine when, where, and if control measures are warranted from an entomological standpoint. Objectives for 1951 were 1) to determine a method of sampling that will yield reliable indices of overwintering and active feeding populations, and 2) to determine possible relationships between overwintering populations, active feeding populations, and subsequent defoliation.

Although studies of a preparatory nature were undertaken in 1950, the 1951 work marked the beginning of serious effort along the foregoing lines. To date field work has been conducted on the Helena National Forest, Montana, where fifteen study areas have been located throughout the Big Belt Mountain Range and on the Continental Divide. The selection of these areas was based on the fact that they were known to represent varying population levels and were thus well suited for purposes of comparison. It is hoped that data gathered from these studies will provide information that will apply to budworm surveys throughout the northern Rocky Mountains.

MEASUREMENT OF INSECT POPULATIONS AND TREE DEFOLIATION

Determination of Overwintering Populations. - Following the methods developed in 1950, larval rearings were made again from bole sections 16 inches in length and cut at midcrown, with a few exceptions noted below. However, techniques of forcing emergence of hibernating larvae were greatly improved.

Bole samples were placed in 5-gallon, cardboard, ice cream containers lined with a special type of moisture-proof paper used for wrapping frozen foods (Fig. 1). In this manner excessive evaporation and ensuing drying of the bark was held to a minimum. Larval emergence was greater from these containers 1/ than that obtained previously from unlined, rectangular, cardboard boxes.

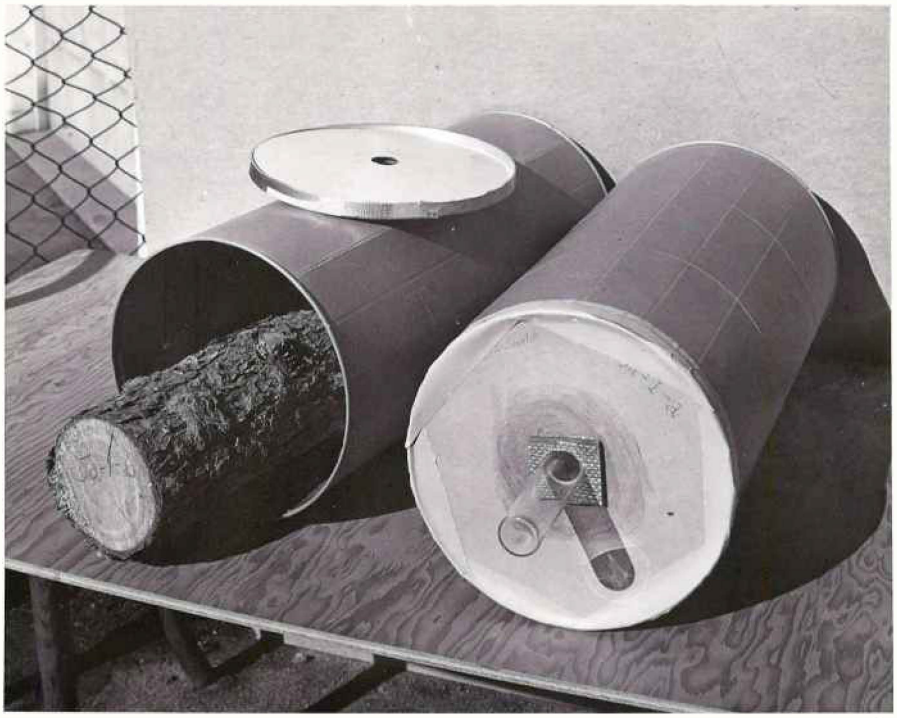

Fig. 1. A 5-gallon, cardboard, ice cream container used to force the emergence of hibernating budworms. (1498, Johnson)

1/ In several localities samples were cut from the same trees, and adjacent to the initial samples collected in December 1950. The improved techniques used in the later rearings yielded nearly 3 times as much emergence as that obtained from the initial samples in the unlined, rectangular boxes.

To determine a more feasible portion of the tree from which to obtain samples of overwintering populations, collections were varied in one locality of heavy infestation to the extent of sampling the bole at the base of the crown and at breast height, as well as at midcrown. This allowed, also, testing the rougher textured bark of the lower trunk for differences in the number of hibernating budworms as compared to the smoother bark in the crown. In this instance the results showed considerable variation. Whereas the average emergence per 100 square inches of bark surface was 62 larvae at midcrown, the number increased sharply to 242 larvae immediately below the base of the crown, and to 309 larvae from a section of bark cut at breast height, well below the crown.1/

These figures not only show the tremendous magnitude attained by budworm populations in this area, but more important, they suggest possible means of conducting appraisal surveys of widespread outbreaks. Thus, for the purpose of larval rearings, if a square foot or more of bark surface can be removed at the base of the tree, several more samples can be collected in the same time that ordinarily would be devoted to felling the tree and removing samples from the bole. The increased number of samples should result in more accurate estimates of the overwintering populations in the areas being surveyed.

Determination of Active Feeding Populations. - During the latter half of June 1951 efforts were made to correlate populations of early instar larvae mining buds with previously determined overwintering populations. If this were possible then hibernating populations per unit area of bark surface could be translated into terms of feeding populations appearing later on a unit of foliage. Thus, samples consisting of 50 buds each were examined for the number mined by larvae, and in each instance the result was tabulated as a percentage of buds infested.

A brief summary of the results of this phase of the study is included here, since the attempts were unsuccessful and will not be dealt with further. Changes in micro-climate caused by differences in exposure or rapid changes in elevation, even within a few acres, caused wide variation in the percentage of buds containing larvae. In one instance, for example, 25 per cent of the buds on twig samples were infested. Nearby, but 100 feet higher, the percentage of mined buds dropped to 15, while 100 feet still higher, no buds were infested but larvae were found preparing to bore into them. In a similar examination one week later, the percentage of mined buds remained constant at the lower elevation, but changed to 26 and 22 at the higher elevations, respectively. In another area 32 per cent of the buds were mined at the time of the initial examination (on this exposure dormancy was breaking and the buds were beginning to swell). A week later the percentage had increased to 48.

These results indicate that micro-climate is perhaps critical in determining the time that budworm hibernation is broken, but even so, emergence occurs over a period of a week or more at any location. Because of this, in some plots larval emergence had not occurred at the time of examination, while in others apparently most of the budworms had already emerged and bored into buds. Thus, the majority of data concerning the active feeding population engaged in mining buds showed no reliable correlation with either the overwintering population or the amount of defoliation.

1/ Trees in this area averaged 8-inches in diameter and 50 feet in height.

Determination of Defoliation. - In the latter part of October the amount of tree defoliation was measured in the various study areas, on the same trees that were used to measure active feeding populations. The percentage of defoliation for each tree was computed from 3 branch samples consisting of 50 current growth terminals each. Thus, the number of defoliated terminals x 2 gave a percentage of defoliation for each sample, and the average of 3 samples was recorded as the percentage of defoliation for the tree. In this manner defoliation was measured on 5 trees in each study area, which gave a total sample of 750 current growth terminals. Fortunately for the purpose of analysis, 1951 defoliation in the several areas varied in amount from almost none to nearly 100 per cent.

In determining the number of defoliated terminals on each branch sample, difficulty was encountered where partial defoliation only had occurred on some of the tips. To standardize computations only those terminals that had 75 per cent or more needles destroyed were considered to be "defoliated". This figure was chosen, after considerable examination had been made of many infested trees, for several reasons:

1. In the majority of cases partial defoliation amounting to less than 75 per cent of the needles on the growth tips was an exception, unless the growth terminals were unusually long or the population was small. This was especially true in areas of greater population densities where competition for food was more acute. Unless the budworm was disturbed it generally seemed to remain on one tip (or tips that were included in the webbing) until practically all of the current foliage was destroyed before moving to a new location.

2. Defoliation of 75 per cent or more of the needles on a terminal was easily discernable to the eye, compared to, say, any significant overall difference between 25 per cent and 50 per cent defoliation per terminal.

3. Where 75 per cent or more of the foliage on the terminals as a whole was destroyed, the branch tips assumed a very ragged or barren appearance. This was not the case when very many terminals had only 50 per cent of the foliage removed.

In effect, the latter argument suggests that perhaps Douglas-fir can withstand a loss of up to 75 per cent of the foliage on each growth terminal for many years, but not 75 per cent or more. This point should receive further study.

RESULTS

Correlation of Overwintering Populations and Subsequent Defoliation. - Comparison of overwintering populations and corresponding defoliation in the various localities showed generally good correlation, with but few discrepancies. In only 4 cases were correlative values found outside of the limits of probability and these, therefore, were discarded. Remaining data are presented in Table 1.

TABLE 1. - COMPARISON OF THE OVERWINTERING POPULATION PER UNIT AREA OF BARK SURFACE AND THE SUBSEQUENT DEFOLIATION PER UNIT OF FOLIAGE.

No. Larvae Per 100 Sq. Ins. Bark Surface	Percentage of Defoliation
1	2
3	1
3	30
4	3
4	15
5	13
6	2
8	30
9	50
11	44
13	50
18	58
22	84
29	85
47	92
66	96
78	98

From this table a graph was constructed by plotting the percentage of defoliation over the number of hibernating budworms and fitting a freehand curve through the points, as illustrated in Figure 2. Examination of this graph shows that the amount of defoliation increases sharply with but a small increase in the corresponding number of budworms, until the amount of larval emergence reaches 10 to 15 per 100 square inches of bark surface. Thereafter, a considerable increase in number of larvae is required to result in material increase in defoliation. Populations above 40 larvae per 100 square inches of bark surface indicate nearly complete defoliation, which approaches 100 per cent with a population of about 80 larvae per unit of sample.

The differences between several of the actual values as measured in the field and those assigned by the freehand curve indicate that, due to factors such as errors in sampling techniques, no exact or specific relationship exists between the percentage of defoliation and a given number of overwintering larvae. For practical purposes, therefore, the range of defoliation that might be expected to result from a corresponding range of larval emergence is presented in Table 2.

A pertinent point in connection with this table is that populations greater than 40 larvae per 100 square inches of bark surface apparently have little significance in furthering the total amount of defoliation. In fact, it is even conceivable that such populations might be more desirable than, say, 20 to 25 larvae per unit sample - allowing a more rapid buildup of parasites, and accelerating any spread of disease or the effects of starvation.

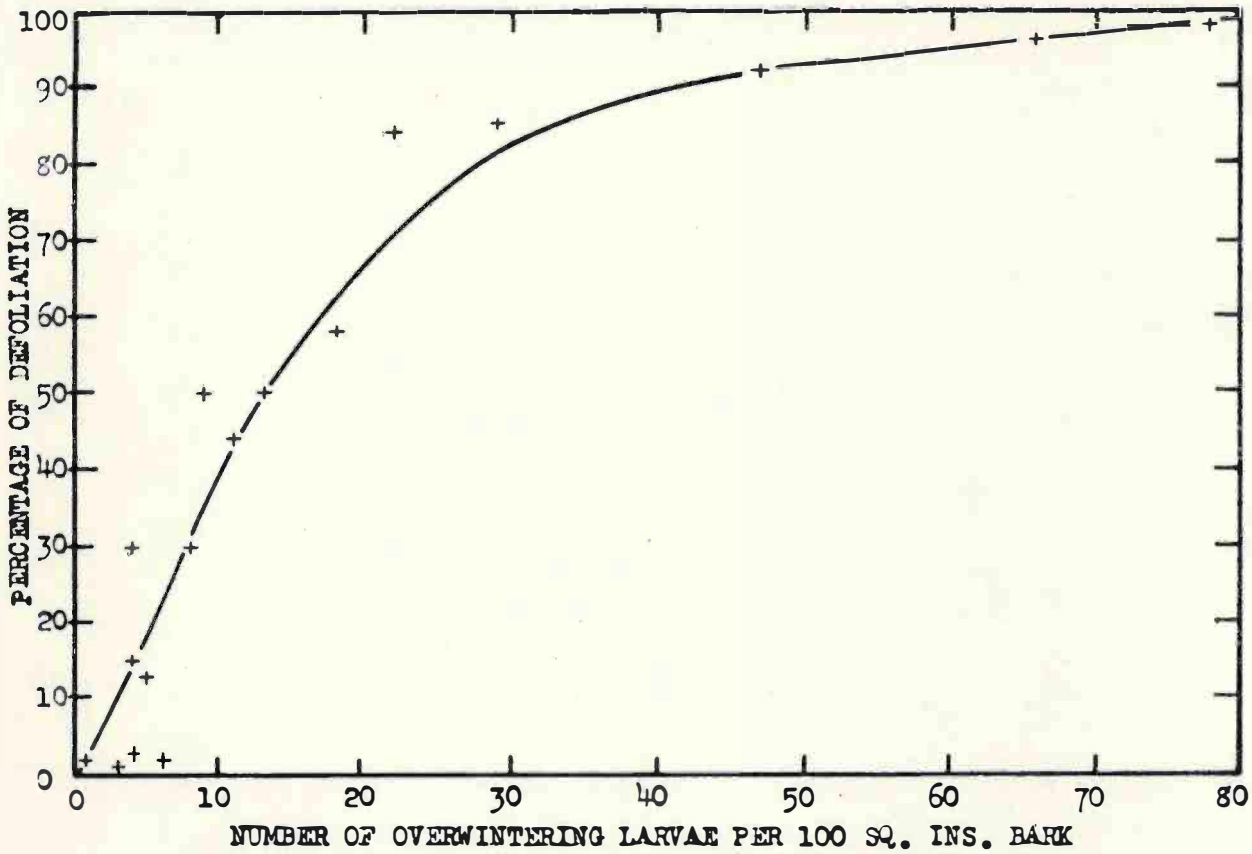

Fig. 2. Freehand curve estimates of the percentage of defoliation resulting from varying densities of overwintering budworm populations.

TABLE 2.- RANGE OF DEFOLIATION IN PERCENT RESULTING FROM CORRESPONDING RANGE IN NUMBER OF OVERWINTERING LARVAE PER 100 SQ. INS. BARK SURFACE

No. Larvae Per 100 Sq. Ins. Bark Surface	Percentage of Defoliation Estimated From Freehand Curve
0 - 5	0 - 20
5 - 10	20 - 40
10 - 15	40 - 55
15 - 20	55 - 65
20 - 25	65 - 75
25 - 30	75 - 80
30 - 40	80 - 90
40+	90 - 100

This type of data does not lend itself readily to statistical analysis. It was possible, however, to compute the standard error of residuals (that is, the differences between the actual values plotted from field measurements and those estimated from the curve), which amounted to ± 9 per cent. However, it is recognized that this figure in itself is not necessarily a measure of the accuracy of the curve. The validity of the data will be tested in the field during the coming season by predicting the percentage of defoliation in each study area as indicated by the amount of larval emergence from rearings in the spring of 1952, and checking the results by field measurements in the fall.

DISCUSSION

Determination of Overwintering Populations. - The problem of determining the magnitude of overwintering budworm populations by forcing their emergence from bole sections is difficult for several reasons. Foremost among these is that factors such as the length of time required to fell each tree and cut a section of bole, together with the weight and bulk of such sections, tend to limit or reduce the number of samples that can be economically and feasibly collected in each area. Because of this, accuracy of the resulting data - in regard to correlation with subsequent defoliation - is dependent upon the selection of "average" trees, as to both size and bark texture, that will yield a true index of the existing population.

Also, this method of sampling does not permit the correlation of overwintering populations and defoliation on the same trees, thus introducing another variable if any significant differences exist between overwintering populations on individual trees. For the purpose of this study (that is, to be able to predict the amount of defoliation from a given number of larvae per unit sample) it is desirable to establish as nearly as possible the definite percentage of defoliation that resulted from a measured number of hibernating budworms.

The possibility of overcoming the foregoing difficulties by determining overwintering populations from bark samples taken at the base of the tree presumes similar conditions for all intensities of infestations; that is, even in light infestations a relative number of larvae hibernate at the base as compared with heavy infestations. Whether or not this is true remains to be proven.

Correlation of Overwintering Populations and Subsequent Defoliation. - The freehand curve illustrated in Figure 2 was fitted by balancing the sums of residuals on either side of the curve. It may be seen that the curve is drawn upward by a relatively few, scattered measurements haveing rather large deviations. Yet it is believed that the general shape of the curve portrays conditions in the field quite well. Evidently, a comparatively small number of larvae can consume a considerable amount of foliage, but at a certain population density the effects of competition for food become manifest and thereafter starvation probably accounts for the diminishing slope of the curve. In all situations observed, however, it is peculiar that even at very high population levels slight, if any, feeding occurred on older than current growth in spite of starvation.

The unusually low percentages of defoliation, namely, 1, 3, and 2 resulting from 3, 4, and 6 larvae per unit sample, respectively, might be accounted for by the fact that partial defoliation of growth terminals was not taken into consideration. As was previously brought out the occurrence of only partially defoliated tips was more prevalent in light population densities. Adjusting the method of measuring defoliation to include this factor might result in even closer correlation between overwintering populations and defoliation.

PLANS FOR FURTHER STUDY

The correlations that have been obtained to date have been of sufficient significance to warrant the continuation of this study for at least another 2 seasons. Efforts in 1952 will be directed to 1) testing the possibility of sampling bark at the base of trees to determine overwintering populations, 2) correlating the abovementioned hibernating populations and subsequent defoliation, and 3) collecting data concerning the relationship between a given percentage of defoliation and the death of the tree.

The effects of several natural factors on the success or failure of predicting the amount of defoliation from larval rearings will be studied, also. In one area, for example, the parasite Glypta fumiferanae (Vier.) was found very abundant in 1951. In other areas along the Continental Divide a tremendous flight of budworm moths was attracted away from the forest by the lights of Helena, Montana. Factors such as these might change the budworm status over large areas of forest in a single season, and yet knowledge concerning this possibility is lacking.

The relationship between hibernating populations and defoliation that has been determined thus far in the study is already proving of practical value. Two relatively small budworm control projects are scheduled for the summer of 1952, and spring rearings of overwintering populations will be conducted to substantiate the need for control. By so doing, areas on which control will be applied can be delineated, and likewise other areas can be excluded if the rearings indicate that only slight damage may be expected to occur during the coming season.